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Fire and the compartmentation of buildings

by J. H. McGuire

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No building is free from the threat of fire. A designer, however, can ensure that only limited damage will result if fire breaks out by reducing the over-all fire risk. There are various means at his disposal, but the single design feature that will contribute most to this reduction of risk is his use of fire-resistant construction to separate a building into fire-resistant compartments.

Fire-resistant construction may be described as construction that continues to fulfil its function during the course of a fire, and where walls, floors and partitions are involved prevents the transmission of fire beyond these boundaries. It must not be confused with non-combustible construction, which may or may not have the requisite degree of fire resistance in a given set of circumstances. It is, however, frequently necessary to resort to largely non-combustible construction in order to achieve substantial fire endurance (i.e. a long fire resistance time).

The fire resistance or fire endurance of a structural element is universally defined in terms of the length of time it will meet certain requirements when exposed in a test furnace that follows a specified time-temperature curve. For a particular building the fire endurance requirements are in turn related to the fire load within it.

Fire Load

The fire load of a building is the heat of combustion of the component materials and contents per unit floor area of each storey. Most combustible materials found in buildings are of a cellulosic nature, for which the heat of combustion may be taken as 8,000 Btu/lb, but for some materials (e.g. petroleum fuels) the value can be as much as 20,000 Btu/lb. A convenient source for more detailed information is the *Handbook of Fire Protection* issued by the National Fire Protection Association, Boston, Massachussetts.

A relationship between fire load and duration of a fire, corresponding to fire resistance furnace exposure, was first developed in the U.S.A. in 1928 and is summarized in Table I.

TABLE I
AMERICAN RESULTS

Combustible Content		Equivalent Severity of Fire in Hours of Standard Test
Weight lb/sq ft	Fire Load* Btu/sq ft	
10	80,000	1
15	120,000	1½
20	160,000	2
30	240,000	3
40	320,000	4½
50	380,000	6
60	432,000	7½

* Calorific value of materials taken as 7000-8000 Btu/lb.

Subsequent work carried out at the British Building Research Station led to the recommendations given in Table II; these differ appreciably at higher fire loads. The discrepancy between the two tables is probably associated with the fact that fire resistance requirements should not, strictly speaking, be related solely to fire load.

Since buildings in any one category of occupancy will probably have similar fire loads, the intermediate step of referring to fire load is often omitted when building codes are formulated. Fire resistance requirements, in terms of time, are often specified directly for the various categories of occupancy into which buildings can be divided. Such an approach assumes that fire load will be dependent solely on occupancy, and although this is only an approximation the problem involved in fram-

TABLE II
BRITISH RECOMMENDATIONS

Weight lb/sq ft	Fire Load Btu/sq ft	Equivalent Severity of Fire in Hours of Standard Test
13	Less than 100,000 (low fire load)	1
13 - 27	100,000-200,000 (moderate fire load)	2
27 - 55	200,000-400,000 (high fire load)	4

ing building codes appears to necessitate such a simplification.

Size of Compartment

Probably the most important issue the designer must consider is the size and nature of the compartments into which he should divide a building. His choice will depend on considerations of life and property risks, which in turn will be influenced by such factors as the probability of an outbreak of fire in various locations throughout the building and the proportions to which such a fire can be allowed to develop. The probability of fire may be assessed to a degree from an examination of the statistical reports that are usually issued from time to time by the appropriate department of the central government of a country. In Canada such reports are issued annually by the Dominion Fire Commissioner. In a very crude way the probability may also be estimated from a consideration of the special risks that may be involved in the actual use of the building. It cannot be said, however, that this subject is yet capable of a very satisfactory scientific treatment.

An interesting feature of many building codes, and one that may be taken as an illustration of the application of the above concept, is the allowance of larger areas if sprinkler protection is provided. Sprinkler protection reduces the probability of the development of a substantial fire. Hence, it is logical on a statistical basis to permit a larger compartment area where such protection is provided in order to establish the same over-all risk. Over the years the incidence of fire will be lower, although any one fire may impose a larger loss. If sprinklers are installed many building codes permit an increase in area by a factor of two.

The concept of determining in advance the extent to which a fire will be allowed to develop before it is controlled or extinguished may appear to be unorthodox. In fact, the design of the building will regulate this development within remarkably close limits. Although fire fighting might succeed in restricting the dimensions of a fire to less that those of the fire-resistant compartment involved, the designer should, in the first instance, disregard this possibility and assume that the fire will involve the whole of the compartment in which it originates. As a general rule the size of the compartment will have been chosen to reduce life and property risks to economically acceptable proportions.

An assessment of the appropriate size of compartments with regard to life risk is not simple, but it may be approximated by considering whether the prescribed hypothetical boundaries of the fire will cut off escape routes of the occupants of various parts of the building. Almost universally it can be recommended that separate storeys should constitute separate compartments, and further subdivision will very often also be desirable.

When property risks are considered, the basis of a suitable choice of size of compartment becomes more obvious. One of the principles may be illustrated by the following examples. A fire-resistant safe in which jewellery is stored may be taken as a limiting case of a compartment from various points of view. The probability that fire will originate in the safe is remote. It is the object of the fire-resistant construction to protect valuable property from fire originating in neighbouring compartments. The argument for confining a paint spray booth by fire-resistant construction is almost exactly the reverse. The value of the materials within the compartment is small, but the probability of fire substantial. The primary object of fire-resistant construction in this case is to protect lives and property in adjacent compartments.

Where life and property risks are both low compartments may be large. The question arises as to what upper limits should be set. This is still a matter of dispute, but a popular concept maintains that one of the dimensions of a compartment should not exceed twice the maximum effective range of an average fire hose, which is of the order 60 to 120 feet. It is not desirable that a fire-resistant compartment should be more than one storey high.

Special Compartments

Certain fire-resistant compartments will be of a very special nature. In all high buildings staircases, whether for normal use or specifically intended as escape stairwells, must constitute fire-resistant compartments with direct access to the exterior of the building at ground level. It should not be inferred that the construction of a staircase as a fire-resistant compartment will detract from its appearance. In fact, it need not be apparent to the eye that it is self-contained and fire-resistant. The main staircase in a building may differ, however, from escape stairwells in that the building finish materials are not necessarily of a type that will minimize the possibility of a primary fire in this area.

The interrelationship of the various compartments of a building, particularly the escape stairwells, will have a substantial influence on life safety. It is desirable that a large building should have at least two escape stairwells. If possible, the areas between two such stairwells should be divided into at least two compartments. Under these circumstances, assuming that the appropriate doors are closed immediately on the outbreak of a fire, it is most unlikely that both stairwells would become smoke logged and impassable at the same time. Smoke migration is such a pernicious phenomenon that flow around one door is often sufficient to foul the compartment immediately adjacent to the one on fire.

Other compartments of a special nature will include elevator shafts and shafts that might be required for convenience in distribution of services. The general principles underlying the design of these completely enclosed shafts is obvious enough to need no elaboration. The remarks which follow on the question of doors can be taken to apply to elevator doors.

The use of a shaft from top to bottom of a building to carry services is not fundamentally objectionable provided it constitutes a fire-resistant compartment. It is probable, however, that the quantity of combustible materials involved, for example in the insulation of electric cables, would be sufficient to allow a substantial fire to develop in the area. It must, therefore, be remembered that various service facilities could be seriously disrupted throughout the building by such a fire. For this reason it might be desirable to exclude from this shaft certain services such as emergency lighting and the wiring of an automatic fire detection system.

Closure in Fire-resistant Construction

One of the problems in dividing a building into compartments is that some links between them are almost invariably essential. Services will usually be common and a number of cables, pipes, and ducts will be required to pass through the fire-resistant partitions bounding the various compartments. Pipes should present no problem. Careful patching of the wall where it is penetrated should be satisfactory. Electric cable will generally penetrate the wall via a conduit. With most acceptable modern cables it is improbable that the materials themselves will propagate the fire from one side of a boundary to the other, but sealing of the conduit on the two sides is necessary, if only to reduce the transmission of smoke.

More detailed attention is necessary for air ducts, each of which requires at least one damper that will provide a fairly effective gas seal. On several counts it is desirable that there should be two dampers, one on each side of the partition. In this way an effective seal can be achieved regardless of the sign or direction of the pressure difference between the two compartments. Two dampers with an appreciable (e.g. 6-inch) separation between them would also tend to reduce the probability of ignition of materials on the unexposed side of the partition by thermal conduction along the duct material. It is desirable in any case that combustible materials should not be in contact with the duct for some 6 inches to a foot on either side of the partition.

The most difficult problem is presented by the necessity for free passage between compartments under normal conditions; it may well be equally essential during the preliminary stages of a fire. Doors constituting parts of the boundaries of a fire-resistant compartment must have some measure of fire endurance. To achieve an appropriate measure is often not easy. In addition, some consideration must be given to what constitutes appropriate fire resistance. A fire resistance of several hours may be required of some partitions, although the doors forming part of them may be expected to have the appearance of simple, relatively lightweight, conventional ones. In many instances wired glass will meet the requirements, for doors incorporating wired glass can achieve a fire resistance of an hour or more. Fire resistance in this context need not involve a temperature requirement at the unexposed surface, for it can be ensured that combustible materials will not be placed very near to them.

Where fire endurance times of the order of hours are involved, it may not be practical to expect a door to have the performance of the remainder of the structure, even if the temperature requirement is waived. Where a very great measure of fire safety is desirable it can be achieved by using two doors separated by some few feet, the construction of the area between them being non-combustible and fire resistant. A simpler approach would be to reduce to a reasonable minimum the area of the wired glass involved, and to ensure that building materials for several feet on either side of the doors are non-combustible and the construction fire resistant. Thus, if some flaming were to occur in the region of the unexposed face from leakage of flammable gases around the door it would not be likely to initiate a developing fire. A further complementary approach would be to install on either side of the door sprinklers of a type that could be remotely operated by some means on the outbreak of fire.

When subjected to fire, doors will probably be distorted. It is difficult to generalize regarding their suitability, but before a choice is made the results of fire resistance tests should be studied. A door should remain an effective fire stop for a period of at least 30 minutes so that the escape of occupants from other areas of the building will not be impaired by the spread of fire. On this count the door should also remain a reasonably effective gas seal for the same period in order to reduce problems associated with the migration of smoke. In most circumstances it should be possible to select doors that will retain some measure of effectiveness for the whole period of fire endurance required of the compartment involved, although the above requirement may be relaxed to some extent where it is considered that fire fighting can be effective in the region of the unexposed surface.

Closing of Doors

No reference has yet been made to how the doors and dampers described will be closed in the event of fire. Where migration of smoke is not considered a problem the use of fusible links will often be effective. It is, of course, fundamental that doors should never be wedged open, although it should be assumed that they will frequently need to be held open. Suitable means for achieving this under the control of a device such as a fusible link should be incorporated. The fusible link, however, is not the best device possible. It is quite possible that fire will occasionally propagate to the next compartment prior to the operation of the fusible link. Furthermore, it is almost certain that large quantities of smoke will flow into the next compartment before the fusible link operates. The term "smoke" is here loosely applied to the gaseous products of combustion, many of which can constitute a serious life hazard. Alternatives to the fusible link include automatic door-closing mechanisms or simple electro-magnetic door catches released by manual fire alarms or automatic fire detecting systems. Automatic door-closing devices can be most effective but are, in general, expensive. The electro-magnetically operated door release can be equally effective but need not be expensive. Its use would, of course, be effective only on doors fitted with the door-closing mechanisms currently found in most modern buildings.

Fire Resistance and Life Safety

The fire resistance requirements so far discussed have all been related to the duration of the fire, but if complete destruction of the property is tolerable a modified concept may be introduced. Evacuation of the building would then be the only feature to be considered. A suitable fire resistance recommendation might be that all elements should comply with structural requirements for 1 hour and temperature requirements for 30 minutes. This discrepancy in time is suggested on the basis that collapse constitutes a serious impediment to escape, whereas waiving the temperature criteria after 30 minutes merely gives rise to the possibility that a fire might develop (involving time for development) on the far side of the partition involved.

Such an approach must be given the most careful thought. It can only be valid where adequate warning can be expected from detection and alarm systems, and where it is known that the response to an alarm will be the complete evacuation of the building. Special provision may be necessary where there are infant, senile or restrained occupants.